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Mass occurrence of Gyrodinium aureolum Hulburt and fish mortality along the southern coast of Norway in September-October 1981

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ABSTRACT

At the end of September 1981 the sea appeared "coffee brown" along the southern coast of Norway due to mass occurrence of Gyrodinium aureolum Hulburt. The maximum cell concentration observed was $70 \cdot 10^6$ cells$\cdot l^{-1}$. When most abundant, the algae formed a more or less continuous, brownish belt from the Oslofjord to the Flekkefjord area, extending up to 30 km off the coast. From all along the coast fish mortality associated with brown water was reported. The mortality was mainly among fish kept in nets and cages, but dead wild fish and invertebrates were also observed. Measurements of oxygen and light microscopy on gills from moribund fish indicated that neither lack of oxygen nor physical clogging of the gills caused the mortality.

INTRODUCTION

Gyrodinium aureolum (Hulburt) was orginally described from the northeast coast of U.S.A. (HULBURT 1957). It was first recorded in European waters in 1966 (BRAARUD and HEIMDAL 1970) when a bloom along the southern and western coast of Norway discoloured the sea and was associated with fish mortality. Since then *G. aureolum* has bloomed several times in Northern European waters, and mortality among fish and invertebrates has often coincided with the blooms (HANSEN *et al.* 1969, HELM *et al.* 1974, TANGEN 1977, BOALCH 1979, FORSTER 1979, GRIFFITHS *et al.* 1979, OTTWAY *et al.* 1979, CROSS and SOUTHGATE 1980, LEAHY 1980 and JENKINSON and CONNORS 1980).

At the end of September 1981 the sea along the southern coast of Norway appeared "coffee brown" due to mass occurrence of *G. aureolum*. From all along the coast fish mortality associated with the brown water was reported. This communication reports some results from studies during the bloom.

MATERIAL AND METHODS

Water samples were collected along the coast from the Oslofjord to the Flekkefjord area (Fig. 1). Temperature and salinity were measured. The number of *Gyrodinium aureolum* cells were counted after fixation with formaldehyde in a Palmer-Maloney slide (PALMER and MALONEY 1954) without any concentration of the samples.

At Borås Fish farm and in the Rosfjord (Fig. 2) where heavy fish mortality occurred, water samples for oxygen determination were taken. Intensive sampling in Flødevigen Bay (Fig. 2) over a 20 hour period on September 28-29 also included measurements of oxygen.

The horizontal and vertical distribution of the bloom and the hydrographical and hydrochemical situation was studied during a cruise on October 4-7 (Fig. 2).

Dead and moribund fish, and gills from moribund fish were examined to see if there was any obvious explanation to the mortality. Some fish were frozen and sent to Veterinarian authorities for closer studies. The gills from a few fish were cut away and fixed for electronmicroscopy studies.

RESULTS AND DISCUSSION

The distribution of the bloom

September 7 1981 on a routine cruise along the section Torungen (Arendal)-Hirtshals at a station about 10 nautical miles off the Danish coast (Hirtshals), $0.3 \cdot 10^6$ cells$\cdot l^{-1}$ of *Gyrodinium aureolum* were recorded at 20-30 m depth.

Fishermen along the coast observed patches of brown water between September 21-27 which may have been the first appearance of the *Gyrodinium aureolum* bloom. On September 28 the algae formed a more or less continuous, "coffee brown" belt along the coast from the Oslofjord to the Flekkefjord area, extending up to 30 km off the coast according to fishermen's information (Fig. 1).

On and after that day reports of mortality among fish kept in nets and cages and also among fish in the sea came from the same stretch of the coast. The reports seemed to correspond to the very peak of the bloom moving westwards with the coastal current (AURE 1981). Northwest of the Flekkefjord area the continuous belt of brown water ended, but patches of brown water due to mass occurrence of *G. aureolum* were observed north to Bergen causing local fish mortality (AURE 1981). Compared to the rest of the coast, the *G. aureolum* bloom penetrated somewhat delayed into the Oslofjord (KARL TANGEN, Univ. of Oslo, pers. comm.). Quite sensationally the algae bloomed further north along the Norwegian coast in June 1982 and two fish farms on the island Senja (Northern Norway) lost more than 50 000 salmon altogether (ANON 1982). It seems likely that this bloom was based on initial populations of *G. aureolum* from the bloom along the coast of Southern

Norway in the autumn 1981 which had survived through the winter.

The cruise on October 4-7, (Fig. 2), was just after the very peak of the bloom. The sections A and B were taken on October 4 in a variable, gentle breeze. Brownish water, with more than $2 \cdot 10^6$ $cells \cdot l^{-1}$ extended nearly 20 km off the coast along section A. Along both sections the highest cell concentrations, more than $8 \cdot 10^6$ $cells \cdot l^{-1}$, were observed in the upper 2-3 m. The vertical distribution of the cells seemed to fit the isohalines rather well, (Fig. 2), i.e. the cell concentration decreased with depth as the salinity increased. Section C was taken October 5 during a strong breeze from the WNW. Because of the heavy waves G. aureolum was mixed more homogeneously in the upper 10 m especially at station C_2 (Fig. 2). When sampling along section D, on October 6, the wind had turned to ESE and decreased to a fair breeze. G. aureolum was fairly homogenously distributed in the surface layer along the whole section with concentrations from 1 to $2 \cdot 10^6$ $cells \cdot l^{-1}$. The data from the cruise indicate that the horizontal and vertical distribution of G. aureolum may change rapidly due to prevailing winds and currents.

The temperatures were 12-15°C in watermasses discoloured by G. aureolum during the whole blooming period.

The causes of the bloom are thought to be the presence of an initial population of G. aureolum together with rich nutrient supply and favourable hydrographical conditions due to upwelling, heavy precipitation and fresh water run off (DAHL et al. in prep.).

Vertical migration

During a 20 hour period on September 28-29, the Gyrodinium aureolum bloom was studied in Flødevigen Bay (Fig. 2) by sampling down to 18 m depth every fourth hour. In the evening on September 28 $30 \cdot 10^6$ $cells \cdot l^{-1}$ was recorded at the surface, but only $2 \cdot 10^6$ $cells \cdot l^{-1}$ at 1 m depth. At 5 and 8 m depth $0.7 \cdot 10^6$ $cells \cdot l^{-1}$ were recorded (Fig. 3).

During the night the cell concentrations decreased to less than $5 \cdot 10^6 \cdot l^{-1}$ at the surface and increased significantly at 5 and 8 m depths to $3 \cdot 10^6$ cells$\cdot l^{-1}$. The following day the highest concentration, $22 \cdot 10^6$ cells$\cdot l^{-1}$, was observed at 0.5 m depth, and the cell concentration decreased rapidly with the depth to less than $0.1 \cdot 10^6$ cells$\cdot l^{-1}$ at 5 m depth and deeper.

The weather during the study was calm, and the salinity (Fig. 3) indicate only minor vertical mixing. Thus the change in vertical distribution of G. aureolum observed during the 20 hour study strongly indicated positive phototaxis. Phototaxis has been noticed also during previous blooms of G. aureolum (see TANGEN 1977 and references therein).

There was no evidence of serious deoxygenation during night in the Fløvigen Bay (Fig. 3). It was never less than about 90% saturation at the bottom (18 m), and supersaturation was recorded in the surface layer through the whole night.

Observations on fish and invertebrates

According to fishermen observations the fish avoided the brown water and, for example, fishing for mackerel was locally spoiled for some days.

Cod and eel in nets died within 24 hours when influenced by heavily brownish water. Some fishermen succeeded in keeping their eels alive by lowering the nets to 10 m depth or more before the eel were seriously affected by the brown water.

When rainbow trout were dying at Borås Fish farm on September 28, there were about $16 \cdot 10^6$ cells$\cdot l^{-1}$ of Gyrodinium aureolum outside the cage and about $6 \cdot 10^6$ cells$\cdot l^{-1}$ inside (Table 1). The chlorophyll a concentration was 311 and 139 $\mu g \cdot l^{-1}$ respectively. This is up to 10 times more than found during the spring bloom peak in the Skagerrak (DAHL and DANIELSSEN 1981). There were significant supersaturation of oxygen, 110-180%, both inside and outside the cage in the upper 2 meters (Table 1). Low levels of dissolved oxygen, which have been suggested as a cause of previous fish mortality associated with G. aureolum blooms (TANGEN 1977) was certainly not the reason for this fish mortality. Physical clogging of the gills due to mass occurrence of G. aureolum has also been suggested as a possibel explanation of fish mortality (PARKER 1980 cited in PYBUS 1980). However, when observing gills from moribund fish in the light microscope, only small traces of G. aureolum cells could be seen. The cell concentration inside the cage was about at the level one would expect from the salinity data (Table 1) and was mainly caused by vertical mixing due to movements of the fishes.

On October 2 a lot of dead fish drifted ashore in Rosfjord (Fig. 2). The next day the species listed in Table 2 were identified; altogether several hundreds individuals on a small part of the beach. A large number of dead starfish, sea urchins, cockles and bristle worms were also observed. Moribund common periwinkle closed themselves only very slowly when touched with a needle.

The concentration of G. aureolum in the Rosfjord on October 2 was extremely high, about $70 \cdot 10^6$ cells$\cdot l^{-1}$ at the surface (Table 3) which caused a "Secchi-depth" of 0.1 m. The cell concentrations decreased with the depth to $5 \cdot 10^6$ cells$\cdot l^{-1}$ at 3 m and only $0.04 \cdot 10^6 \cdot l^{-1}$ at 10 m. The oxygen level was reduced to about 60% saturation at the surface, but increased with depth to a slight supersaturation at 5 and 10 m depths (Table 3). The watermasses below 10 m were also rich in oxygen. Thus a possible lack of dissolved oxygen in the Rosfjord causing fish mortality is unlikely according to the present observations. October 5 the algae concentration had decreased to $11 \cdot 10^6$ cells$\cdot l^{-1}$ at the surface decreasing with depth, and the levels of oxygen was about the same as on October 2 except for supersaturation at the surface.

A fisherman caught dead ballan wrasse, cod and pollack when trawling for prawns at about 150 m depth in the Rosfjord on October 2. On October 5 he also trawled and all seemed again normal to him except for lack of pollack in the catch. The reason why Gyrodinium aureolum caused mass death of wild fish especially in the Rosfjord was probably due to the particular topography and hydrography in this fjord. It has a deep sill at about 70 m and receive only small amounts of fresh water. BROCKMANN et al. (1981) observed a total change of watermasses down to more than 50 m in the course of one day only in the fjord. Thus the dead fish might have been enclosed by a sudden influx of brown water from the sea outside without any possibilities to avoid.

Previously fish mortality along the Norwegian coast associated with mass occurrence of G. aureolum mainly affected fish enclosed in nets and cages (BRAARUD and HEIMDAL 1970 and TANGEN 1977). HANSEN et al. (1969) reported, however, mass mortality among wild fish along the west coast of Denmark associated with mass occurrence of a naked dinoflagellate, which was determined as Gymnodinium breve (?). According to their photos and description of the algae, it is likely that it was G. aureolum (TANGEN 1977). JENKINSON and CONNORS (1980) also observed various dead wild fishes on a shore during a bloom of G. aureolum in Ireland.

The reason why mass occurrence of G. aureolum cause mortality among fish and invertebrates is not clear. We suppose, however, that neither physical clogging of the gills nor lack of dissolved oxygen are probable explanations. Studies by WIDDOWS et al. (1979) suggest that G. aureolum either produces or contains a substance which is cytotoxic to Mytilus edulis. Thus also fish mortality may be due to such a toxin.

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Table 1. The distribution of <u>Gyrodinium aureolum</u> and salinity, temperature and oxygen measured at Borås fishfarm September 28 1981 when fish mortality occured

Depth m	G. aur. $mill \cdot l^{-1}$	Chl. a $ug \cdot l^{-1}$	Sal. ‰	Temp. °C	O_2 $ml \cdot l^{-1}$	O_2 %-sat.
0	-	314	23.59	14.4	11.30	180.9
0.5	16	311	23.67	14.5	9.79	157.2
1	-	191	23.71	14.4	9.04	144.8
2	-	144	23.85	14.4	7.56	121.3
3	-	25	24.05	14.4	6.55	105.2
5	-	7.5	24.68	14.3	5.94	95.4
7	-	3.7	25.16	14.3	5.69	91.8
10	-	1.8	27.27	14.4	5.13	83.9
0.5^x	6	139	23.74	14.4	8.71	139.6
2^x	-	54	23.97	14.4	7.00	112.4

x - data from the cage

Table 2. Species of dead fish observed in the Rosfjord

Agonus cataphractus	- pogge
Anguilla anguilla	- eel
Ammodytes sp.	- sand eels
Belone belone	- garfish
Ctenolabrus rupestris	- gold-sinny
Gadus merlangus	- whiting
Gadus minutus	- poor cod
Gadus morhua	- cod
Gadus poutassou	- blue whiting
Gadus pollachius	- pollack
Labrus berggylta	- ballan wrasse
Labrus ossifagus	- cuckoo wrasse
Merluccius merluccius	- hake
Molva molva	- ling
Myoxocephalus scorpius	- sea scorpion
Pleuronectes flesus	- flounder
Raniceps raninus	- lesser fork-beard
Syngnathus typhle	- broad-nosed pipefish

Table 3. The distribution of Gyrodinium aureolum and salinity, temperature and oxygen measured at the farthest end of the Rosfjord October 2 1981 one day after fish mortality

Depth m	G. aur. $mill \cdot l^{-1}$	Chl. a $ug \cdot l^{-1}$	Sal. ‰	Temp. °C	O_2 $ml \cdot l^{-1}$	O_2 %-sat.
0	70	1840	19.87	13.8	-	-
1	35	560	24.19	14.0	5.71	90.9
2	15	130	25.06	14.0	5.96	95.4
3	5	75	25.22	14.0	6.17	99.0
5	1.3	26	25.36	14.1	6.35	102.1
10	0.04	4	25.76	14.1	6.75	108.7
15	0.01	1.0	30.63	13.9	5.10	84.3
20	0.01	0.9	32.15	13.2	5.12	84.4
28	0.01	0.4	32.66	11.8	5.14	82.4
0^x	65	-	-	13.8	4.03	62.3

x - data from a near by quay

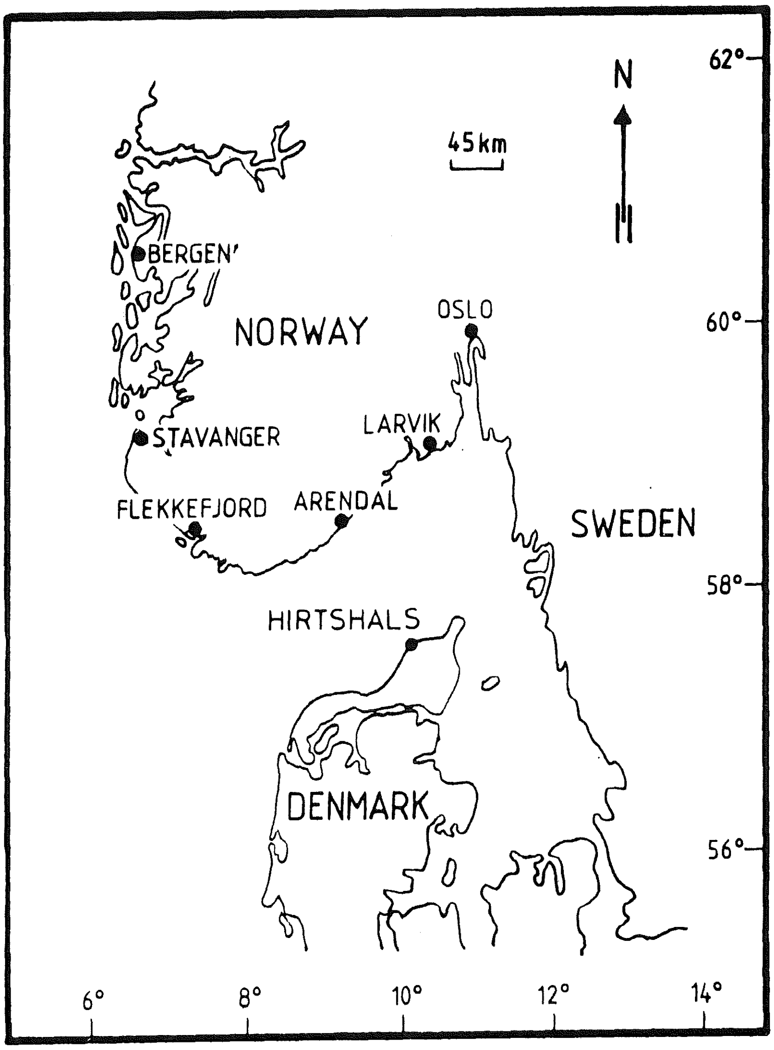

Fig. 1. The southern coast of Norway.

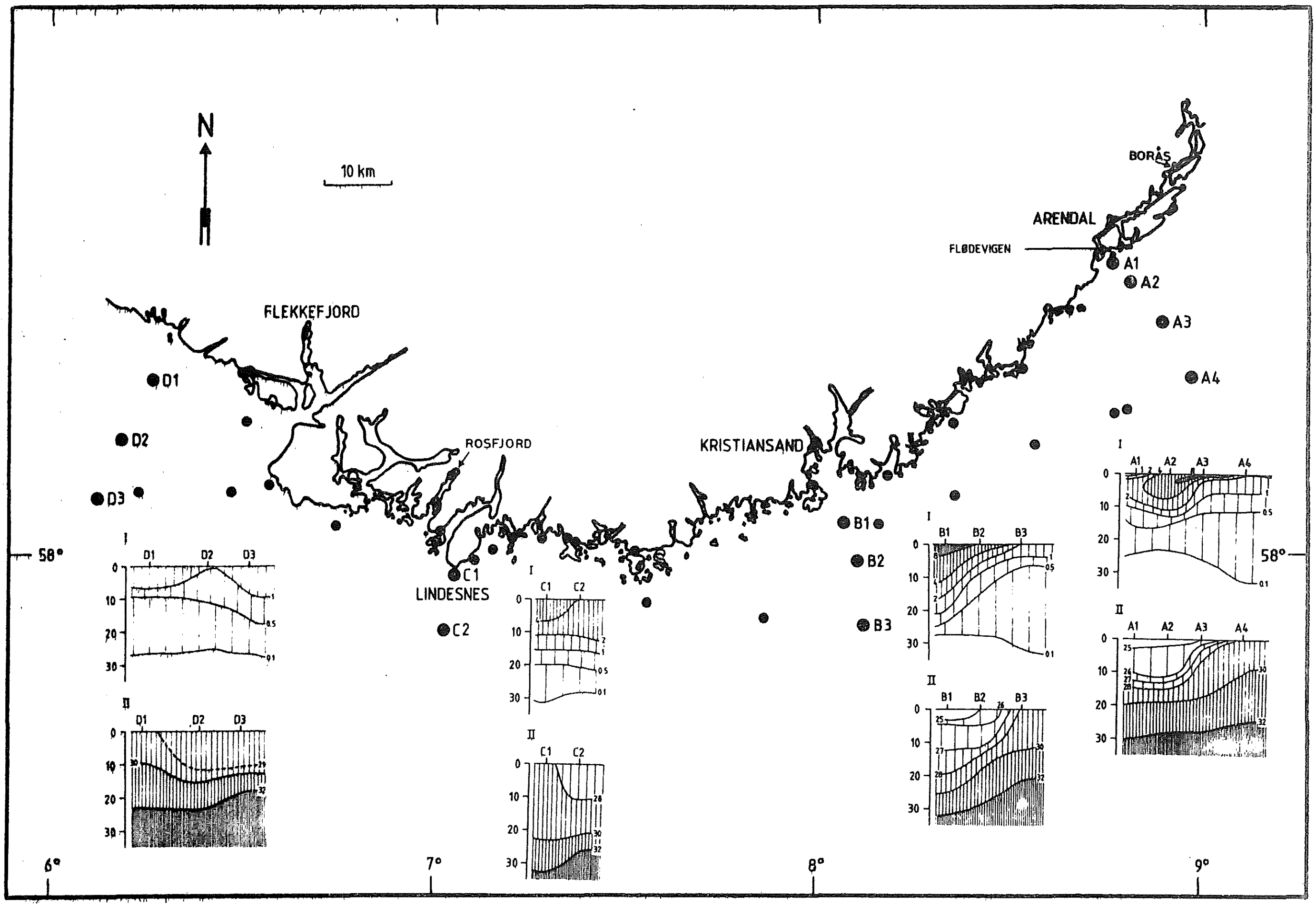

Fig. 2. The sections A, B, C and D and other stations (smaller dots) sampled during the cruise October 4-7 1981. The isopleths down to 30 m depth show:
I - <u>Gyrodinium aureolum</u> (10^6 cells$\cdot l^{-1}$)
II - the salinity (^{o}/oo)

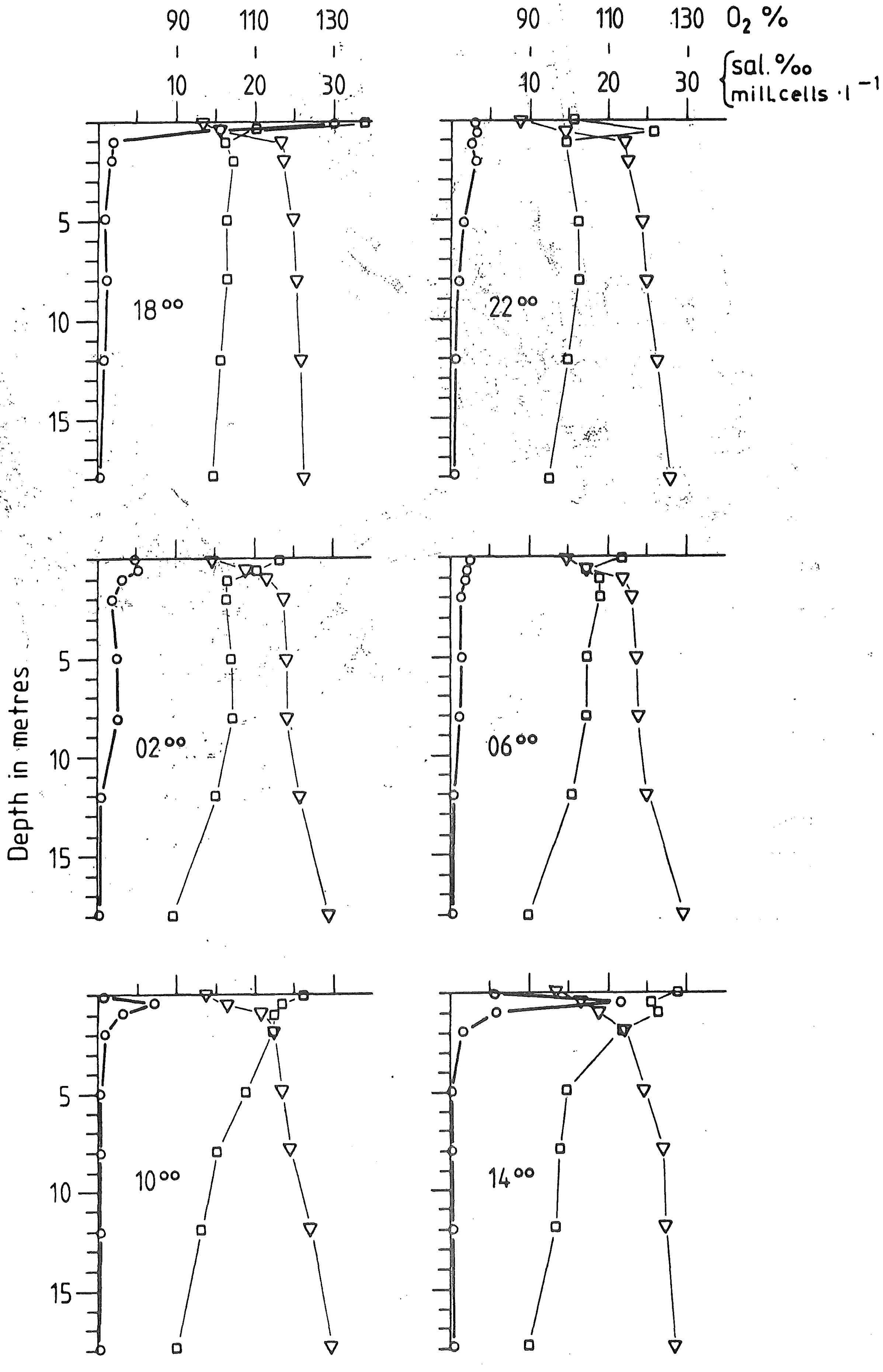

Fig. 3. The vertical distribution of <u>Gyrodinium aureolum</u> (o), salinity (▽) and oxygen saturation (□) in the Flødevigen Bay September 28-29 1981.